

## Using Gliders to Resolve Dynamics of Dust and Phytoplankton in the Mediterranean

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### LONG-TERM GOALS

Optical properties are complex representing variable contributions of phytoplankton, Colored Dissolved Organic Matter (CDOM), marine and atmospherically derived non-algal particles. The relative contributions of these are particularly complex for enclosed inland seas such as the Mediterranean. Results have shown that it is especially critical to collect regional ocean color data from satellites, which must be complemented with spatial subsurface measurements, which can be measured with the physical/optical sensor packages mounted on Webb gliders. We propose to use Webb Gliders to provide a regional subsurface physical and optical dataset to support ship-based NASA, NATO, and ONR efforts being conducted in the Mediterranean in late spring 2008 and early autumn 2009. The Gliders will be used to map the subsurface features over monthly timescales and assess to what degree the non-algal particles are spatially and temporally correlated in space and time.

### OBJECTIVES

Specific objectives of this research include the following:

- 1) use several Webb Gliders to provide a regional subsurface physical and optical dataset to support ship-based NASA, NATO, and ONR efforts being conducted in the Mediterranean in late spring 2008 and early Autumn 2009,
- 2) coordinate the activities of a fleet Gliders that are outfitted with a variety of sensors to quantify the physical hydrography of the coastal and offshore waters in the Mediterranean, the apparent and inherent optical properties, and a range of fluorescence measurements,

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3) demonstrate a web-based Glider Operation Center for Gliders with fleet control being transferred between operators on the ship, personnel at the NATO facility at La Spenzia, and scientists & students in United States throughout the 2-month long experiment and,

4) use the data to understand physical and optical dynamics in the Mediterranean with a focus on understanding the relative importance of atmospherically derived sub-micron dust particles and phytoplankton to determining the derived satellite data products.

## APPROACH

The research in the recent year consisted of the following tasks:

*Task 1: We will use optically outfitted gliders to spatially map the upper water column optics prior to ship-based efforts in the Mediterranean.* With ONR support a bio-optical glider has been developed. In collaboration with Michael Twardowski (WetLabs Inc.) and Clayton Jones (Webb Research Inc.), we have integrated the AUVB scattering sensor. These scattering sensors will be complemented with WetLabs pucks, which will provide the measurements of spectral backscatter. The pucks will also provide measurements of the fluorescence of Chlorophyll a (Chl a) and Colored Dissolved Organic Matter (CDOM) fluorescence. Finally the apparent optical measurements will be made with an upward OCR Satlantic multi-spectral radiometer. These measurements will provide a detailed picture of the in-water optics measurements. The gliders will be deployed one month prior to the ship cruise and provide near real-time data back support shore side planning prior to the cruise.

*Task 2: Partake in NATO, ONR, and NASA efforts to calibrate the remote sensing reflectance of the international constellation of the ocean color satellites.* Efforts will focus on using the multiple Gliders to map full satellite pixels to complement detailed ship-based measurements of the in-water optical properties. The Gliders deployed prior to the cruise will be recovered and new batteries will be installed prior to the cruise. The gliders will then be deployed from the ship during each of the cruise's master stations and the gliders will fly a spatial map that spans a full satellite pixel over the course of several days.

*Task 3: Transfer the Rutgers Glider Operation Center (GOC) to the NATO SACLANT efforts. This transfer will be accompanied with Glider training.* The transfer of the GOC will be transferred with Rutgers personnel who will travel and deploy the infrastructure at the NATO base. The infrastructure will be tested during the Glider effort in the Fall 2008. The Glider training will be focused during a suite of formal classes that will be held both at Rutgers and at La Spezia. These training courses will include participants from NATO, NRL, Industry, and NAVO.

## WORK COMPLETED

The Glider training was held in two forums. The first dedicated military training was held at Rutgers in the Spring 2008. This training, leveraged with funds of the Glider TTI, included personal from NRL, NAVO, NATO, and academics from Europe. The four day workshop was highly successful and included hands-on training of preparing and deploying Gliders. The training also included a full lesson on the analysis of glider data (Fig. 1). The second training will be held in La Spezia the last week of October in 2008. The class has been subscribed by over 60 participants, and much of the hands-on training will utilize the Rutgers Gliders which will have been recovered from the field effort the weekend before. The Gliders have been deployed on the shelf at the end of the month in

September. The Gliders have been flying effectively since then. During the deployment, Rutgers personnel focused on the installing GOC capabilities at the NATO effort. These efforts will continue through the month of October.

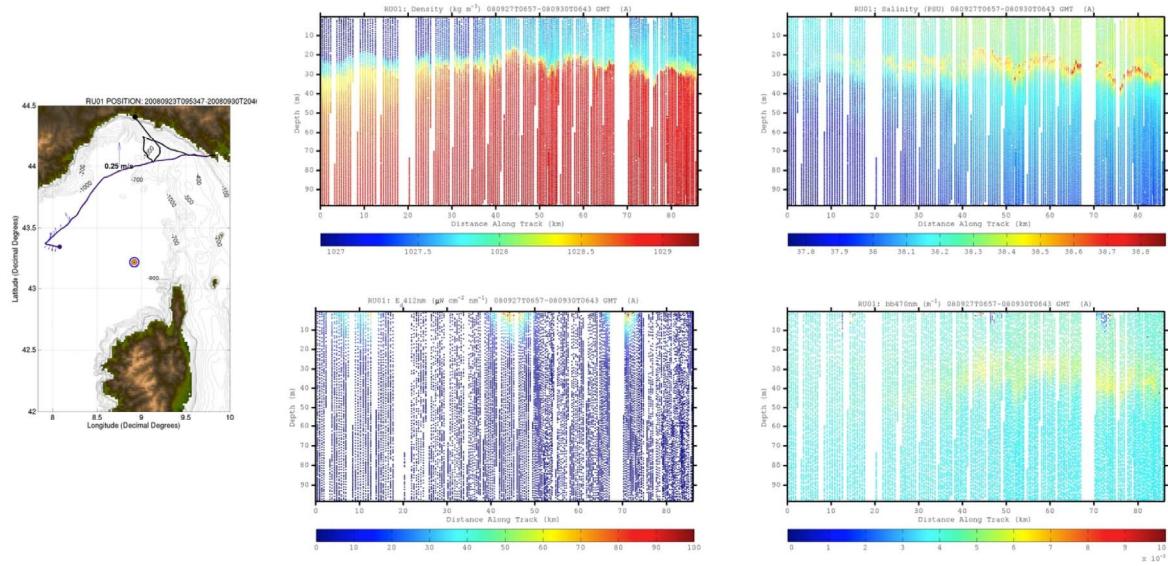


*Figure 1. Navy training on Gliders at Rutgers in Spring 2008.*

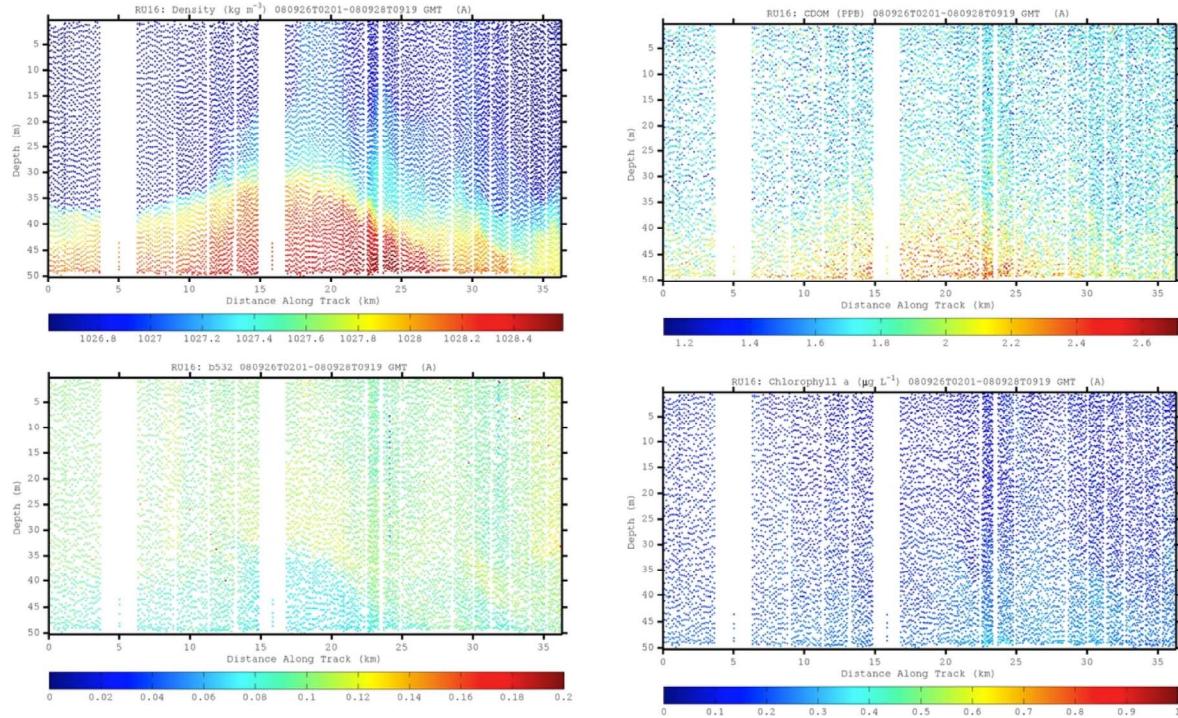
## RESULTS

The Gliders have been deployed. Progress has been followed using the Rutgers blog web site (<http://www.i-cool.org/>). Current progress has one glider transversing on the offshore (Figure 2). A nearshore Glider was recovered early this week due to a leak. The system is being repaired and it will be redeployed in the coming week. Current results show a range of optical properties. As of September 30, 2008 the offshore glider shows that waters are stratified. The nearshore waters show higher salinity values and there appears to be a particle layer found at around 40 meters depth. Light propagation is easily detected down 20 meters water depth. The nearshore glider also showed stratification (Figure 3). There appeared to be 10 meter oscillations in the pycnocline. The waters below the pycnoclines appear to be enriched in Colored Dissolved Organic Matter (CDOM). In contrast the surface waters exhibited enhanced particle loads which were uniformly distributed throughout the upper mixed layer. Interestingly the chlorophyll is not enhanced in the surface waters. This suggests that the particles in the upper water are not phytoplankton. Our hypothesis was that the particles in the upper water may reflect the presence of submicron dust particles which can remain in the upper water column for months at a time. Given the CDOM levels were low and salinity was high in the surface waters indicates that particles were not associated with the buoyant river plumes again consistent with the particles being delivered via the atmosphere.

In 2009, the Rutgers gliders were deployed to La Spezia. Rutgers personnel also joined the ship based cruise during the calibration and validation efforts. The gliders were deployed for short term deployments to complement the ship efforts. The glider control was turned over to the NATO personnel. This represents a significant advance with the maturation of their glider operation capabilities. The data is currently being analyzed and will be prepared for publication.



**Figure 2.** The current data collected by Rutgers Glider Ru01 in September 2008. The data plotted includes data collected by the evening of September 30, 2008.



**Figure 3.** The data collected by Rutgers Glider 16 before being recovered.

## IMPACT/APPLICATIONS

The Navy's mission has transitioned from a deep blue water tactical theatre to a littoral environment; however present Naval operational capabilities do not have the required data fidelity to deal with the complexity of coastal waters. These shortcomings are compounded as traditional sampling approaches

are quickly compromised in denied access regions. The development of a long duration covert capability for collecting environmental (hydrographic and optical) data will offer a new paradigm in solving this problem. Using mine counter measures as an example, optical data would feed back on submersed and aircraft laser line scan mission planning by impacting the effective depth at which the laser can “see”. If the environmental characterization is performed over relevant scales the applications will assist real world missions, including mine detection and mine-counter measures, Special Forces operations, amphibious landings, shallow water anti-submarine warfare and force protection from terrorism

## **RELATED PROJECTS**

We have been actively collaborating with NATO Undersea Research Center and NAVOCEANO on this effort. All data is being freely share. Discussion has been initiated how glider optical data might integrated into the ONR WOOD database. Data will be burned to data CD's and will be made available via one-way FTP. Ongoing field efforts also distribute data in real-time over the world-wide-web (currently the site routinely has over 150,000 hits/day) by the general public, Naval METOC groups, NAVO, NOAA, and the European partners. The data will be distributed to fellow PIs. Developing the optical capability for gliders will directly benefit a recently funded Major University Research Initiative (MURI) which will develop a data assimilative physical-optical modeling-observation system consisting of an ensemble of optical models of varying complexity. This MURI will study the regulation of ocean color for a broad western boundary continental shelf with a specific focus on regions of high optical variability (fronts), which coincides with regions of high acoustic uncertainty.

## **PUBLICATIONS**

Two manuscripts are preparation. One manuscript is under revision for the Marine Technology Society, the revision will be submitted in the next week as there is a November 2 due date. We have been invited to provide an overview of global ocean observatories in the Encyclopedia of Sustainability Science and Technology to be published by Springer Verlag in 2011.